Under the Microscope

December 2021

Issue 3

Expansion

image of earth | credit- NASA

EDITORS' NOTE

We've made it to the third issue of Under the Microscope!! Our previous issues have been full of tons of brilliant articles and this is no different. Our chosen theme is 'expansion' and this was chosen to try and get people to look at how expansion can be seen all across different STEM subjects. This issue is our current team's last issue and it's safe to say that creating this magazine has been an amazing experience for us. However, we have a great team lined up to take over, and can't wait to see what they do! So, without further ado, get reading!!

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BINOMIAL EXPANSION

By Laila Samarsinghe

When we want to times out a polynomial, such as (x+y)^2, it is relatively easy to times out the brackets and see that (x+y)(x+y)=x2+2xy+y2. However, as the power gets larger, multiplying out the brackets becomes a less efficient way ofgetting our result.

If we were to look at some(x+y) polynomialswith increasing powers, we would start to see a pattern.

(x+y)^1=x+y

(x+y)^2=x2+2xy+y2

(x+y)^3=x3+3x2y+3y2x+y3

etc.

You may notice that the coefficients (the numbers in front of the powers of x and y) show a certain arrangement, which can be organised neatly in a pyramid shape, known as Pascal's triangle:

11

121

1331

14641

etc.

(add the two numbers above to get the number below. The first number is always 1 and the second number is always the power of the polynomial.)

So now we can use Pascal's Triangle to figure out the coefficients, without having to times out the brackets. For example, the fourth level of Pascal's Triangle is 1 4 6 4 1, and if we were to multiply out the brackets of (x+y)^4,we would get x^4+4x^3y+6x^2y^2+4xy^3+y^4.

However, it is often difficult to write out Pascal's Triangle every time we need to

multiply out a polynomial, especially as we just need to be able to find the numbers on the row of that power.

As we already know, the first and last numbers will always be 1. The second number will always be the power, or row number (which we will call n). In addition, the power of x decreases and the power of y increases by 1 as we move along, so we always have some form of x^(n-r+1)y^(r-1), where n is the power of the polynomial and each number is the rth in the row.

Using (x+y)^4=1x^4y^0+4x^3y^1+6x^2y^2+4x^1y^3+1x^0y^4 , we can see thatthe power of x (n-r+1) and the power of y (r-1) always equal the power of the polynomial (n).

In (x+y)^4, or(x+y)(x+y)(x+y)(x+y),we can see that there is only one way to get x^4,and this is if we only choose the x from each bracket. In the same way, you can only get y^4 once. So that is why you only get one x^4 and one y^4 in (x+y)^4. However, there are more ways to get x^3. For example, if we listed out the possibilities of what we could choose from each bracket to get an x^3 we would get xxxy,xxyx,xyxx and yxxx. There are four possibilities, so there is 4x^3y in (x+y)4. We could continue writing out all the possibilities to work out how many x^2y^2we can find, but it would be easier to use combinations. For example, to find the number of x^2y^2's, we can find how many ways there are to choose two x's out of the four brackets. This can be written as 4 choose 2 and is calculated by doing 4!/2!(4-2)!. This is (4x3x2x1)/(2x1x2x1) which comes to 24/4 which is 6, so there are 6x^2y^2's in (x+y)4.

If we come back to our notation of the power being n, and r being the position number in the line, then we can use the combinations formula of n!/r!(n-r)! to work out n choose r, which gives us the number of any given x^(n-r+1)y^(r-1)'s in a polynomial.

So, if we were to multiply out (X+Y)^n, we can use the formula to say there will be:

n!/1!(n-1)!X^n + n!/2!(n-2)!X^(n-1)Y + n!/3!(n-3)!X^(n-2Y^2)etc.

This formula can be used for any form of (x+y)^n, for example if we had (323a+11b)n, we could simply substitute in 323a=x and 11b=y into the formula.

Binomial expansion is really useful when having to times out a polynomial, as it stops us from having to write out all the brackets and simplifying it.

Cultured Meat: Expansion of the Food Industry

By Ghazal Ershadi-Oskoui

Cultured meat is real meat that is produced from cell cultures of animal cells outside the animal's body. The production of cultured meat allows for people to acquire the taste and nutrients of traditional meat, whilst preventing the cruelty to animals. Although plant-based meat has developed a prominent space in the food industry over the years, cultured meat allows us to eat real meat guilt-free without compromising on health benefits (e.g., haem iron which is only found in red meat). Sounds great, right? The reason why so many of us haven't yet switched to this seemingly ideal alternative is because it is still in its early stages, with financial issues being one of the largest setbacks.

In 2013, Mark Post at Maastricht University in the Netherlands became the first to create a cultured beef burger patty. It came at the costly price of $300,000 and required two years to produce due to being made from over 20,000 thin strands of muscle tissue. The concept of cultured meat was popularised in the early 2000s by Jason Matheny who created the first non-profit organisation dedicated to research about cultured meat (New Harvest). However, most of the research and development for cultured meat is done privately. Research, development, and commercialisation is very expensive, and the private sector sees potential in this technology, whilst the government has completely ignored it. It would be better if public institutions could nurture cellular agriculture and support it with public investment, regulation, and licensing, as, with state investment, the cost for the consumer will be cheaper, whereas with private firms, they will focus on maximising investor value rather than social welfare.

How exactly does the production of cultured meat work? Cultured meat is created by painlessly harvesting muscle cells from a living animal. Scientists then feed and nurture the cells in a lab, so they multiply to create muscle tissue, which is the main component of the meat we eat. It is biologically identical as the meat tissue that comes from a farm animal. The cells grow into strands; twenty thousand of these small strands of meat are then combined to create one normal-sized burger patty!

There are so many disadvantages to livestock farming. Squeezing animals into factory farms - called concentrated animal feeding operations (CAFOs) has increased the likelihood of outbreaks of zoonotic diseases (diseases

that pass from animals or insects to humans) such as swine flu, avian influenza, or COVID-19. The rate of deforestation has increased as farmers clear land for more feed crops. Looking at cattle farming, there are serious negative environmental impacts posed; cows produce a lot of gases such as hydrogen sulphide, ammonia and methane which are harmful to the environment. Cattle farming also contributes to water pollution. Yes, industrial animal agriculture does affect our water. CAFOs generate millions, if not billions, of gallons of animal waste per year. Animal waste is stored either in pits or in open ponds called lagoons; these waste-containment areas often leak and can rupture during large storms. This can cause surface and groundwater contamination which not only seriously threatens aquatic ecosystems, but also public health due to the excessive nitrates in drinking water, which also stem from CAFO pollution. It is no secret that non-organic meat has antibiotics and hormones to control disease and aid growth. A big problem with these antibiotics inside meat has been that they increase the risk of antibiotic resistance in humans as well. According to the Centres for Disease Control and Prevention (CDC), antibiotic resistance is annually responsible for 25,000 deaths in the European Union and 23,000 annual deaths in the U.S. As many as 2 million U.S. individuals develop a drug-resistant infection each year. By the year 2050, some researchers predict that antibiotic resistance will cause 10 million (according to PLOS health) deaths every year, surpassing cancer as the leading cause of mortality worldwide. Additionally, antibiotics are sometimes used to make the animals grow faster. In humans, studies have shown that antibiotics raise the risk of weight gain andobesity, as they wipe out beneficial gutbacteria that help regulate weight. In countries that have banned the use of antibiotics in livestock to promote growth (such as the US), antibiotics can still be used to prevent bacterial diseases in flocks and herds (something that the World Health Organisation is trying to ban as well due to the risk of antibiotic resistance). Every time antibiotics are used (whether in animals or humans), you risk selecting drug-resistant bacteria which is why the use of antibiotics must be safeguarded to avoid the resistance of them (when used to treat infections).

According to Nicola Evans — a doctoral researcher in structural biology at King's College London, there are a few main ways in which antibiotics in animals can affect humans. Firstly, direct contact between animals and humans can cause disease. She said: "farmers are at risk of being colonised by the Livestock-Associated MRSA (LA-MRSA), which isn't as dangerous as [Hospital-Associated]-MRSA as it is adapted for animals and does not spread as easily from person to person. However, there is a risk that bacteria could change and adapt to humans," Evans warned. She went on to quote a Danish study that found that 40% of commercially sold pork meat contained methicillin-resistant Staphylococcus aureus (MRSA).

Not only is livestock a threat to our health but also challenges food sustainability. The Food and Agriculture Organisation of the United Nations (FAO) estimates that the demand for meat is going to increase by more than two thirds in the next 40 years and current production methods are not sustainable. The long-term goal of food sustainability is to produce enough food to maintain the human population. Soon both meat and other staple foods are likely to become expensive luxury items, because of the increased demand on crops for meat production, unless we consume a sustainable alternative: cultured meat. If lab-grown meat can be produced in some affordable price by state funding, it will be made more accessible to all. However, there is the problem that many people are not willing to eat meat that is grown in a lab. How would it be advertised in an appealing way? How long would it take for cultured meat to replace farmed meat? Would this even ever happen? These are all difficult questions which do not have simple answers.

A cultured beef burger patty

The biology of fibrodysplasia ossificans progressiva

By Sarah Hazell

Fibrodysplasia ossificans progressiva (also known as FOP or stoneman disease) is a progressive disease of the body's connective tissues which affects roughly 1 in 1.6million people worldwide. It causes the muscles, tendons and ligaments of those affected to gradually become ossified (turn into heterotopic bone). This leads to restriction in movement due to fusion of joints as well as difficulty breathing, speaking and eating from the formation of bone around the jaw bone and ribcage (restricting lung expansion).

Diagnosis of the disease is generally made during early childhood. Babies with FOP are often born with malformed big toes with large bunions, angled growth or a missing joint as well as short thumbs and other skeletal abnormalities, distinguishing them from others with similar conditions. The disease develops with periods of ossification flare-up, usually beginning before the age of 10 in the neck, jaw and shoulders with viral infection and tissue-injury being the largest risk factors for it. Overtime, these flare-ups become larger and more severe. As the volume of extra-skeletal bone increases, symptoms worsen and eventually cause death. The most common cause of death in people with FOP is cardiorespiratory failure (heart attack) and the median life expectancy is 42 years.

In 2006, amutation of the ACVR1 geneon chromosome 2q23-24 which codes for a bone morphogenic protein (BMP) required for the replacement of cartilage by bone tissue in normal skeletal maturation was identified to be responsible for FOP. A substitution in codon 206 from arginine to histidine leads to overactivation of of ACVR1, causing endothelial cells to turn into mesenchymal stem

cells and finally osteoblasts (bone cells). The vast majority of cases are caused by spontaneous gamete mutations in the gene. However, in rare cases the autosomal dominant mutation is inherited by a person with an affected parent. The substitution causes a change in the tertiary structure of ACVR1 with the deletion of a ligand-binding domain. Without the ligand-binding domain, the cytoplasmic protein FKBP12 binds to BMP receptors on cell-surface membranes instead. Usually, ligand-binding would result in the phosphorylation of type 1 by type 2 BMP receptors. However, the FKBP12 protein forms a complex which reduces kinase production of type 1 and causes only type 2 to be phosphorylated. This causes eventual complete type 1 receptor activation and much higher volumes of protein production which promotes the disease's characteristic differentiation of connective tissue cells into bone.

Currently there are no cures or approved treatments for FOP. However, patients are very commonly administered pain relief and anti-inflammatory drugs in an effort to ease some of the side-effects attributed with the condition and improve their quality of life. Many surgical procedures have been carried out to remove large sections of the excess bone, but unfortunately, they have been unsuccessful as they were only shown to cause further injury-induced flare ups. However, there are several on going clinical trials creating drugs for FOP and drugs suppressing its progression are likely to be effective in the future.

Fibrodysplasia ossificans progressiva.
(Joh-co / Wikimedia Commons)

The importance of COVID-19 in the expansion of vaccine technology

By Holly Dulieu

The COVID-19 pandemic has led to the fast, mass production of vaccines. Only 12 months after the first cases of Covid were reported, two vaccines had already been developed,had been authorised for use in the UnitedStates, andhad begun being deployed all over the world. Since the development of these successful vaccines, pharmaceutical companies have turned to attempting to develop vaccines for longer- term diseases, most notably HIV.

The Covid jabs produced by Moderna (a firm based in Massachusetts, USA) and Pfizer (also an American company) use mRNA technology. This is a type of nucleic acid vaccine therefore having many advantages over older vaccine approaches, for example whole-pathogen vaccines. Advantages include the speed and ease with which they can be manufactured, and the fact that the encoded immunogenic material does not remain in the human body for a long duration of time.

mRNAtechnology is used to create vaccines which cannot be easily dodged by viruses. They do not use live viruses, instead solely using mRNA which instructs muscle cells to make proteins which trigger an immune response in our bodies. The cells responsible for producing those antibodies become memory cells, therefore making the immune response much quicker when the person is infected with the disease. This is because these cells remember how to make the specific antibodies needed, meaning they can make them faster and at a higher volume than if the person was unvaccinated.

The human immunodeficiency virus (HIV) is the virus which causes AIDS. This refers to multiple illnesses which have the potential to be life-threatening due to the severe weakening of the immune

system caused by HIV. Whilst AIDS cannot be spread from one person to another, HIV can,through methods such as unprotected sex,sharing needles, and transmission from mother to baby during pregnancy or breastfeeding. Unlike Covid vaccines, which were developed and produced very quickly, the attempts at creating a successful vaccine for HIV have spanned across three decades. One American pharmaceutical company, Johnson & Johnson, thought they had made a breakthrough in this development. However, on August 31stthis year, its attempt failed a clinical trial leaving them back where they started.

The reason it has been so challenging to develop a vaccine for HIV is that the virus has a high mutation rate. Therefore, it can adapt to avoid natural immune responses and artificial vaccines. When a person is infected with HIV, antibodies are produced as an attempt to label the pathogen. Most antibodies, however, fail to label the virus due to its continuous evolution and mutation, allowing it to escape our immune system.

In February, the International AIDS Vaccine Initiative (IAVI) conducted a study showing that, in humans, it is possible to stimulate activity in immune cells called germline B-cells. These cellsare able tomake broadly neutralising antibodies against HIV. Germline B-cells, in the presence of a pathogen, are alerted to undergo a process called somatic hypermutation. This process is where germline B-cells produce daughter cells which have the capability of developing the same antibodies only with very slight differences. In this study, a small protein called e0D-GT8 60mer was used to stimulate somatic hypermutation in germline B-cells which carry a specific broadly neutralising antibody called VRC01. All these findings made a solid foundation for a vaccine.

Whilst some may think that this will work as avaccine in itself(injecting the protein e0D-GT8 60mer into those infected with HIV), there are some reasons as to why it is not being used. The main problem with this method is the fact that this engineered protein is both expensive and time-consuming to make.

Advancing vaccine technology stemming from COVID-19 has helped to develop this strong idea into a much more plausible case for a vaccine.

The same mRNA technology, upon which Moderna's covid jab is based on, can be used in this situation. Moderna's HIV vaccine contains the mRNA which instructs cells to make the protein e0D-GT8 60mer themselves instead of containing the protein itself. Therefore, the body's cells can produce the protein, which on entry to the bloodstream, stimulates the work of the germline-B cells which produce the right antibodies to fight off HIV.

This new vaccine technology is currently going through rigorous testing to check its safety and prove that it works. The trial began at the end of September this year, with 56 people in America. Other African countries are also going to be involved in this trial as at the end of 2020 it was estimated that two thirds of those infected with HIV were in Africa.

It is not yet known whether this vaccine trial will prove to be successful or not, however it is a step in the right direction towards the development of a working HIV vaccine. Without this technology used in the making of Covid jabs, this promising vaccine would not exist, and therefore highlights the importance the COVID-19 pandemic has had on expansion of vaccine technology.

WHY URBAN GREENING IS CRUCIAL TO MAINTAIN A HEALTHY SOCIETY

By Rawnaq Islam

I decided to specifically focus on London when researching into this issue and the importance of green spaces in cities, which raised the question: how much of London is green? Well, surprisingly, London is one of the greenest cities, with 47% of its area being green space; this includes parks, gardens and woodlands. 13% of this is also private gardens, however this percentage could have been higher if people had not paved over their gardens, particularly in recent years, to make private parking spaces and patios. This also raises the question as to how much damage rich people and lifestyles have on the environment.

Although we may not always realise it, green spaces in cities have a great importance. Firstly, trees absorb carbon dioxide, in order to photosynthesise. This cleans the air and helps to reduce carbon emissions. The removal of carbon dioxide in the atmosphere reduces the greenhouse effect and, in turn, helps to combat global warming. Trees do all of this while also producing oxygen as a product of photosynthesis, improving air quality and providing us with clean air to breathe. Research has also shown that improved air quality has a direct impact on our physical health as it has decreased the rates of cardiac disease, strokes and asthma. Having open green spaces in urban areas also improves people's mental health and quality of life as these spaces can be used for recreation. The presence of trees in urban areas has also been linked to

protecting biodiversity and providing habitats for London's 13,000 species of wildlife, including habitats for migrating pollinators and birds. New research has also shown that trees could cool cities down by as much as 5 degrees Celsius. Scientists have found that just 40% tree cover can cool streets more than the pavement warms them up. Lastly, one of the key reasons as to why trees are so important, particularly in urban areas, is that they intercept rainwater. This reduces surface run-off, which lowers the river discharge and therefore reduces the risk of flooding. This is crucial as urbanisation continues to increase and the use of impermeable surfaces, such as concrete pavements and tarmac roads, also increases. These surfaces do not allow water to infiltrate through them, leading to an increase in surface run-off which causes a greater risk of flooding. Therefore, trees are able to tackle some of the effects of urbanisation.

To conclude, green spaces in urban areas are more important than we may think they are and trees in particular have been linked to many positive impacts. Boris Johnson has also claimed that by 2050, the area of green spaces in London will have increased by 3%, which brings it up to 50% in total. If this is achieved, we should see more of the positive impacts that green spaces have on us and the environment.

The importance of Fibonnacci's theorem in nature

By Maya Mohammad

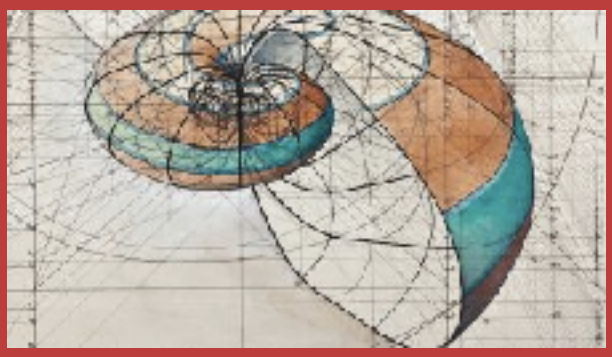
In 1170, a man named Leonardo Pisano Fibonacci, better known as Fibonacci, was born in Pisa, Italy. He was educated in North Africa where his father, Guilielmo, held a diplomatic post. His father was a representative for the merchants of the Republic of Pisa who were trading in Bugia, now known as Bejaia, in northeast Algeria. Fibonacci was first taught maths in Bugia but as his father travelled, so did he, picking up skills of mathematics from the countries he visited. After many years of travels, Fibonacci returned to Pisa in 1200. Here, he wrote many books which assisted the resurrection of ancient mathematical teachings and he also created many significant contributions of his own. Of these books, we still have copies of Liber abaci (1202), Practica geometriae (1220), Flos (1225), and Liber quadratorum . Unfortunately, we lost many books, including his book on commercial arithmetic Di minor guisa and his commendations on Euclid's elements. This book included many numerical treatments for irrational numbers which Euclid had only approached from a geometric point of view. Fibonacci's life continued in a prosperous way, gaining recognition by all of Pisa along with the Holy Roman emperor and King of Germany, Federick II.

Arguably, Fibonacci's most universally known contribution to mathematics is his finding of Fibonacci numbers, hence the Fibonacci sequence. The problem that led to the creation of this sequence was in his book Liber abaci. It went as follows: 'A certain man put a pair of rabbits in a place surrounded on all sides by a wall. How many pairs of rabbits can be produced from that pair in a year if it is supposed that every month each pair begets a new pair which from the second month on becomes productive?'. The result was 1, 1, 2, 3, 5, 8, 13, 21, 34, 55…., which was the result of each number being the sum of the preceding two numbers. This is the Fibonacci sequence.

This sequence is extremely relevant to nature. The most common result that appears when you look up "fibonacci sequence nature" is plants. Flowers tend to have a fibonacci number of petals. Not only this, but the petals themselves are usually arranged in two spirals going in different directions, these spirals contain two consecutive fibonacci numbers of petals. This is also seen in seed arrangements and pine cones. Fibonacci numbers are also in shells. A perfect spiral can be made from fibonacci numbers. If you align squares with lengths of the fibonacci numbers in a

spiral, and putting a quarter of a circle in each, you get what is called a perfect spiral. Perfect spirals, also known as logarithmic triangles, are seen in the shape of shells of snails and sea shells. Using the fibonacci sequence, we have also found the 'golden ratio'. If you divide each fibonacci number by its preceding number, these numbers produce a sequence tending to a limit, the golden number: (phi), (sqrt5 + 1)/2 (approximately 1.618034). This ratio is also seen in nature, and is why fibonacci numbers are so important in plants. In order to leave the maximum amount of space between seeds, the space must be an irrational number. As it turns out, the golden number is the most irrational number. Therefore, a turn of phi would be the optimal space for seeds and leaves in plants, hence why the opposite turns in seeds and leaves are two consecutive fibonacci numbers.

Whether nature is based around the maths or visa versa is debated. Evolution would suggest that living things evolved to have the most optimal arrangement, and we have now found the maths in it. As humans, we seek to find order and structure in the unknown to make sense of things, and to help us understand. The fibonacci sequence is us finding order and looking for data in the natural world. As humans learn more, more mathematical patters will emerge of our world around us.



"My father, who had been appointed by his country as public notary in the customs at Bugia [...] desired me to stay there and receive instruction in the school of accounting. There, when I had been introduced to the art of the Indians' nine symbols through remarkable teaching, knowledge of the art very soon pleased me above all else and I came to understand it, for whatever was studied by the art in Egypt, Syria, Greece, Sicily and Provence, in all its various forms."
— Fibonacci in Liber Abaci

General practice is in crisis: Why?

By Siciido Muse

GPs (general practitioners) play a huge role within the community. Their role ranges from consultations to referrals for investigations. They also can provide extended primary care services, for instance, immunisation, screening and diagnostic services. They also play an extremely fundamental role in NHS care as GPs usually act as the first point of contact for anyone with a health concern. In 2016, there were 54,024 licensed GPs in England and Scotland. This role they play means they often are assessing the symptoms that their patients display to see if they require referrals or further consultations. They also play a significant role in supporting terminally ill patients who often choose to stay at home. The importance of GPs cannot be overstated. In this article, I will be briefly discussing some factors that contribute to the pressures general practices are under.

There are many reasons as to why general practices are overwhelmed, one of them being that the UK has an ageing population. Around one fifth of the UK population is over the age of 65 (12.3 million people). Since 2009 and 2019, it has increased by 23%. Age impacts people's physical and mental condition and can increase the risk of disease. Many conditions, such as hearing loss and dementia, are associated with older age groups. Over half of people aged 65-74 live with one long term health condition and for people who are 85 and above, it is two thirds. GPs play a huge role in the monitoring and evaluation of conditions that elderly patients have. With more elderly populations, the number of patients visiting their GPs increases.

Another point to consider is that GPs and practice nurses have an increase in immunisations to do without extra provisions given to them. Over the last few years, there has been an increase in numerous vaccines such as the influenza vaccine for young children and pregnant women and the introduction of rotavirus, meningococcal B and meningococcal ACWY vaccines. These vaccines were administered in primary care, building upon the already overwhelming workload on GPs and practice nurses. This is ultimately time-consuming and feeds into the pressures in general practice.

As complex medication is made available, more monitoring is needed such as regular blood tests. GPs often need to monitor and review the effects of these drugs and prescribe them occasionally. There is also an increase in both secondary and primary preventions (for example statins, anticoagulants and antihypertensives). The side effects of drugs can lead to a need for more drugs to treat it and the cycle could go on. This increases the demand for services.

I think another important influence on the pressures on GP is the public health campaigns. For instance, people are advised to consult their GP if they spot any symptoms and signs. Of course, the benefits of this campaign mean that more people recognise signs of common cancer for an early diagnosis and increase the survival rate. However, these campaigns did increase the pressure on GP as attendances would increase.

GPs are also required to complete more non-clinical works such as producing reports and fit notes. Fit notes are something that GPs are required to issue (free of charge) to provide evidence for people who cannot work due to their condition. This is required by many services, such as Universal Credit. However, this isn't just limited to fit notes. Different services ask for evidence from GPs, ranging from schools asking for a letter explaining a student's absence to airlines wanting a letter for carrying a prescription on board a plane. This is asks a lot of general practice. Even though some tasks are not free of charge, this still is something that adds to the workload of GPs.

Overall, there are a lot of factors that influence the pressure that exists for GPs. Besides making this role incredibly unappealing, fewer doctors aspire to enter this job position- making it even more difficult to retain GPs. Many retire early and fewer GPs are taking full-time clinical work. Trainee GPs often turn to work on a salaried basis. Furthermore, the pressure not only impacts GPs, it will also affect the quality of care provided to patients. In recent reports, 85% of patients were able to get an appointment to see a GP from the last time they tried (this went down from 87% from previous years). This ultimately reduces the quality of care given to patients.

This is a large issue that needs to be addressed and improved. I would recommend reading 'General Practice Forward View' and research conducted by 'The Kings Fund' as my article is heavily inspired by their report and they explored these points in more detail.

The Expansion of Medical Imaging: the 3D Microscope

Ghazal Ershadi-Oskoui

Recently, a team of scientists at Umeå University in Sweden came up with a way to create complex and extremely detailed 3D maps of whole organs. The concept of medical imaging was first introduced in 1895 with the invention of the X-ray by Wilhelm Rontgen - a German professor of Physics. In the 1950s, nuclear medicine started to be used as a way to diagnose diseases in the body: the patient is infused with radionucleotides combined with pharmaceutical compounds reaching particularly active organs or groups of cells. These images are then recorded by a gamma camera. This method enables researchers and doctors to detect medical problems earlier than other tests. In the 1970s, the CT (Computed Tomography) scan was developed. This technology takes a series of images of 'slices' of the body and then puts them back together with a computer to visualise internal structures of the body (such as the heart). Magnetic Resonance Imaging (MRI) technology was also invented in the 1970s. This uses strong magnetic fields and radio waves to determine if there is a problem with tissues in the body.

The process of 3D microscopy involves embedding the organ in agarose (a gel substance extracted from red seaweed). The organ's tissue can then be sectioned into cm^3 chunks which are the perfect size to be imaged using Optical Projection Tomography (OPT). This is similar to CT but uses UV or visible light instead of X-rays. These sectioned pieces can then be labelled to visualise any type of cell or protein of choice. Each bit of tissue is given coordinates, meaning that the individual images produced can be pieced together using a computer (like a 3D jigsaw puzzle) to form a whole human organ.

Using this technology makes it possible to create high resolution 3D images of human organs of any size with micrometre precision (smaller than a particle of dust!). Although OPT technology, which has been used in this process as well, already existed and allowed for high-resolution imaging to take place, it is only now that these small sections (like cells and proteins) can be labelled.

So far, the Umeå researchers have used this technology to study the human pancreas. There are hundreds of thousands of insulin-producing cells in the pancreas (called Islets of Langerhans) which play a key role in diabetes. Using this new 3D microscope technology, researchers are now able to see previously unknown area that have a high islet density (in people who have type-2 diabetes). This is very useful because it can help improve islet transplantation techniques. As the imaging technique enables the study of where cellular changes take place, by looking at a whole organ and their relationship with nearby tissues and cells, researchers should be able to study other organs and diseases in similar ways.

As you can see, medical imaging has improved immensely since the first X-rays were taken over 120 years ago. There is much more accuracy in diagnosing a medical problem and there is now no need to perform invasive surgery to explore the body. This hopefully will lead to early diagnosis and better treatment options for many patients.

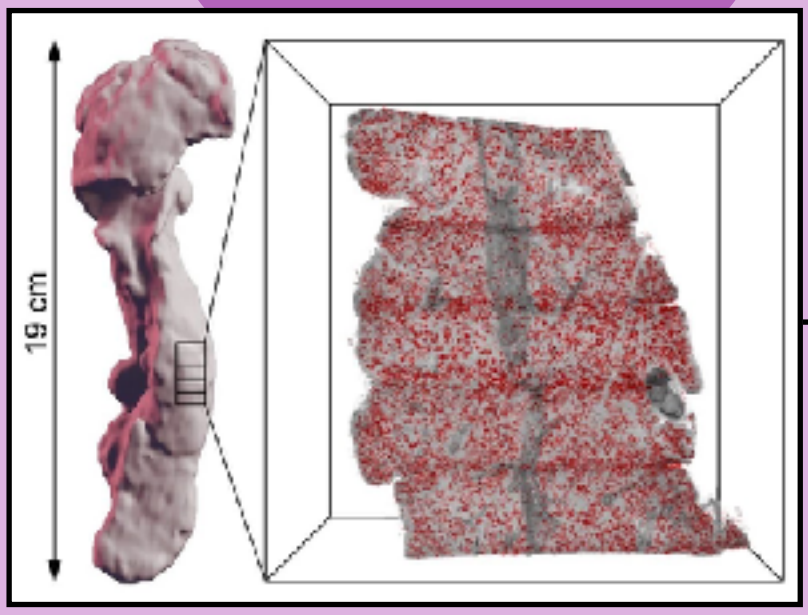


Illustration showing how the pancreas can be scanned in smaller parts and then pieced together to form a three-dimensional image of the whole organ

Racism in healthcare by Rawnaq Islam

Racism is embedded into the depths of society, including within educational institutions, workplaces and the criminal justice system, to mention a few. I have chosen to specifically look into racism in the healthcare system and how racial bias and inequalities affects patients of colour. Racism is prevalent within healthcare itself and can cause doctors to neglect, doubt and even sometimes actively discriminate against patients.

A study conducted in 2016 found that 73% of white medical students in the US believed in at least one misconception about the biological differences between races. Some of these false beliefs include that black people have: a higher pain tolerance than white people, stronger immune systems, thicker skin and less sensitive nerve endings. Racial bias can also prevent many BIPOC from receiving emergency medical care. A US study conducted in 2020 found that between 2005 and 2016, black patients were 10% less likely to be admitted to hospital by medical professionals than their white counterparts. It also found that white people were 1.26 times less likely to die in hospital than black people.

However, patients aren't the only ones who are affected by racism in health care settings, as doctors and other healthcare professionals are also affected. A 2020 study researched into racism experienced by physicians of colour in the health care setting. Its results showed that physicians of colour were exposed to instances of discrimination and racism, quite regularly, while at work. The results displayed that 23% of participants reported that a patient had directly refused their treatment and care specifically due to their race. The symptoms of secondary traumatic stress and microaggressions at work were also shown to be quite significantly linked to each other. The data, from qualitative research, also revealed that the majority of participants had experienced racism from their institutions, colleagues and patients. The study concluded that physicians of colour are quite likely to experience racism and are unlikely to be supported by their institutions while providing care in a health workplace setting. They also suggested that institutions which seek for a fairer environment in a work space should intentionally include and embrace diversity and inclusion as part of their efforts.

Should we allow governments and companies to have access to our DNA?

By Saskia Pearl

DNA profiling companies have risen in pertinence due to recent developments in the field of genomics. Key examples of these are Ancestry.com, with over 15 million users worldwide, and 23andMe, with over 12 million. These DNA tests not only provide customers with information surrounding their ancestry, genetic health, and traits, but also have the potential to link distant relatives together. However, these advances have led to speculation about whether our DNA should be publicised for use by private companies. Working alongside these companies, there is a government entity called the UK National DNA Database. Every profile is derived from a sample of human material, such as saliva or hair, collected from a crime scene. There was a huge controversy raised about this storage and subsequently in 2012, the UK Protection of Freedoms Bill aimed to address the balance between an individual's right to privacy and the State's duty to protect the public. As a result of the change, 1,766,000 DNA profiles taken from innocent adults and children were deleted from the database, along with 1,672,000 fingerprint records. Furthermore, 7,753,000 DNA samples containing sensitive personal biological material were destroyed. The storage of our DNA will only become an increasingly topical and contentious issue as biotechnology advances, and thus it is important to confront it while it is still relatively contained.

The first reason as to why one should allow governments to have access to their DNA is because it could assist police when investigating crimes and identifying suspects. If a match is made between a DNA profile at a crime scene and a DNA profile on the database, the evidence could be instrumental when helping to solve the case. It has been estimated that using the database to find a DNA profile match helps identify a suspect in around 60% of cases in the UK. Furthermore, information stored in databases can be held in different countries, enabling a suspect in one country to be identified in another. Therefore, a DNA database could help keep track of criminals globally. Even though some argue that a DNA database is an exploitation of our biological data, it would be created with the initial aim to help make the world safer. Between 2 and 10% of criminals in the US are wrongly convicted, and thus having a DNA database would provide an extra layer of security.

Secondly, allowing companies to store our DNA could also help with research and discoveries. For example, 23andMe provides consumers the choice of opting into research conducted on behalf of non-profit, industry and academic organisations. They also offer an option to consent separately to specific disease studies in which their DNA is used in conjunction with drug companies, such as the lupus and IBD research conducted with Pfizer and the Parkinson's disease research conducted with Genentech. This proves that sharing DNA can lead to life-changing discoveries and could accelerate the rate at which medical advancements are made. It is also important to have larger volumes of DNA as the more data available, the larger variety in alleles and genes, and the more medical discoveries made.

Alternatively, allowing the government to store our DNA could exacerbate racial profiling, directly disputing the first argument that it would make the world a safer place. The use of DNA databases would have a disproportionate impact on black and Latino individuals, who are already trapped by the criminal justice system in both the USA and the UK. Racial disparities in imprisonment directly translates into the disproportionate collection of African American men having their DNA stored in federal databases. In the USA in 2010, black people accounted for approximately 27 percent of adult arrests at a time when the adult black population was 12 percent. Moreover, Hank Greely estimated that 40% of the US federal database originated from African Americans in 2006. Therefore, this shows that the data that the government collects may not even be equal, and could easily be exploited and misused.

Besides from the government, there are also myriad reasons as to why one should not consent to their DNA being stored by companies. Third party sharing is very common among large companies and the more people that have access to one's DNA, the more vulnerable it is to being hacked. Once it is shared, it is extremely hard to predict what will happen to it and how many people will have access to it. In the USA, health insurers and workplaces are not currently allowed to discriminate based on DNA, however the law does not apply to disability insurance or life insurance, and the current rules could easily be revised. In the future, it is very possible that health insurance could be higher for people who are genetically revealed to be predisposed to certain illnesses, despite the fact that this could be considered unethical and unfair.

I believe that we should be allowed the choice to give governments and companies access to our DNA as, depending on one's genetic and socioeconomic background, it could either have dire consequences or it could benefit them. Social constructs, such as race and gender, have defined our society and must be appreciated when setting out new laws or even making personal decisions. Therefore, since we do not live in a fair and equal society, I believe it should be one's personal choice to consent to the storage of DNA and other forms of private information

Nuclear energy: something to be scared of or the way forwards?

By Sofia Cobham

Nuclear physics is one of the most controversial areas of science, with radioactive waste and the idea of an impending apocalypse creating the public perception and stigma we see surrounding the topic. Hundreds of films and books have been written around 'what if' scenarios to do with nuclear weaponry and radioactivity, but in reality, is nuclear physics as bad as it's made to seem? And if it is, then why does it appear to be the way forwards?

Ever since the initial discovery of x-rays in 1895, people have been fascinated by the concept of radioactivity, except, that fascination slowly morphed into concern as the discoveries went on, with Henri Becquerel's findings of the atom, and Marie Curie's discovery of radium and polonium, people grew to be scared, especially after the Cold War and the arms race for nuclear weaponry between the USSR and the USA, with many people fearing nuclear bombs would be dropped on them at any second – as though they were waiting for a repeat of Hiroshima or Nagasaki. People truly came to fear the idea of anything to do with nuclear physics by the end of the Cold War, inhibiting growth in this specific area, and creating extraordinarily bad public perception.

However, recently, due to the climate crisis, there has been a sudden interest in nuclear energy, leading to advancements and expansion, with the global nuclear generating capacity being expected to rise from 392 GWe in 2019, to 715 GWe by 2050. This is a massive advancement, in that we will be able to provide more people with energy for a much cheaper price. The good thing about nuclear energy is that it doesn't produce greenhouse gases, and therefore won't contribute to global warming overall. It is important to note that nuclear energy can be split into two main components: nuclear fission and nuclear fusion. Nuclear fission produces radioactive waste, which is difficult to dispose of, as well as very expensive. Given that the isotopes used for nuclear fission are high level waste (HLW), it is necessary to let the waste itself decay. The waste must go underwater for five years, and then be sent to dry storage. Whilst it has been decided that deep geological disposal is the best way to get rid of it, it's still a difficult process as the rapidly rising population of Earth is making it harder and harder to find an unpopulated area. Not only this, but there's the matter of getting a supply of radioactive materials, of which only two isotopes can actually be used: uranium-235 and plutonium-239, both of which need to be purified before being used in the reactor. This process is long, and often involves having to enrich ('increase') the material. Uranium-235 only makes up around 0.7% of the world's mined uranium, and so it is necessary to increase the concentration of uranium from 0.7% to 3-5%.To do this, uranium undergoes an oxidisation process; converted to a gaseous form after having been changed from uranium oxide to uranium hexafluoride, put through centrifuges, and is finally separated from the heavier uranium-238 isotope. Even then, not all the uranium-235 is extracted.

To say the least, it's a complicated and time-consuming process, but the results you get from the reactor are often very much worth the effort, with one uranium-235 pellet (just larger than the size of a sugar cube) releasing approximately 80 TJ of energy (80,000,000 MJ), making it about 1.5-2 times better than burning natural gas or oil.

As I mentioned previously, nuclear fission isn't the only form of nuclear energy we can utilise – we can also use the energy of the stars: nuclear fusion. It is the most effective way we have of producing energy, producing more than four times the energy released from a fission reaction. It requires deuterium (^2H) and tritium (^3H), two surprisingly common and plentiful isotopes of hydrogen, with deuterium easily extracted from sea water, and tritium being produced from lithium. This means that we have easy access to the two 'ingredients' necessary for fusion, so what's the drawback? Fusion naturally occurs in stars, and stars are, as we all know, incredibly hot. So it is with little shock that the temperature necessary for fusion exceeds 100,000,000°C and requires immense pressure. This is unnaturally difficult to recreate in lab conditions, and requires the hydrogen ions to become plasmolysed, forcing the electrons on the atoms to overcome the strong nuclear force and break off. This plasma state is required as the isotopes themselves repel one another and will only be able to fuse without their electrons. The final energy we gain from this reaction comes from the mass difference (following the equation of $E = mc^2$) as the final product (helium) is lighter than the initial isotopes themselves. With a few grams of hydrogen, it is possible to release 1 TJ of energy – enough energy for one person in a developing country for 60 years. In the future, this could easily become our staple source of energy, with lithium being a plentiful resource and the reactions so big that not much of it would be needed anyway. The reaction doesn't produce any greenhouse gases and is completely clean, but as of right now, it uses more energy to create the reaction than it releases, rendering it ineffective.

In the science community, there is a joke stating that "nuclear fusion is only 30 years away, and always will be," but with advancements made recently, we have managed to get ourselves around 20 years closer, having had fusion reactions in over 50 countries, but not to a point where it's useful due to the energy required for it. In 2019, British researchers said that we should have affordable fusion by 2040, but now, two years later, we have been told that this may be a possibility by 2030. This is one of the biggest advancements in nuclear physics to have ever happened, showing not only the public that nuclear physics can be used for good, but also that it's possible that we have found a viable way to replace coal, natural gas, and oil as energy sources, enabling us to finally stop using greenhouse gas emitting sources and massively decrease our global carbon footprint.

From the first ever discovery of nuclear physics in 1895, until now, in 2021 when we believe it is possible to effectively utilise the energy of the stars, we have made huge advancements in this area of physics, expanding it over the decades, with the negative imaging of Becquerel's keys, to combining two isotopes to make a different element. And so finally, I pose to you the question: is nuclear physics truly as bad as it is made to appear?

Some of the very strange ways animals give birth

By Zoë Bristow

One of the greatest beauties of evolution is that it seems almost anything can be possible…

Hyenas
Within the hyena clans, the females are the leaders. With three times the amount of testosterone in their bodies than any male, they are more muscular and more aggressive. In fact, they even grow a pseudo-penis, an elongated clitoris out of which they urinate and give birth. This birth is a traumatic, painful and often fatal experience, for cubs and mothers alike. The pseudo-penis can only stretch about one inch in diameter, which means roughly 60% of the litter, which is usually between 1 and 6 cubs large, suffocate during birth, and 20% of mothers suffer from fatal tearing.

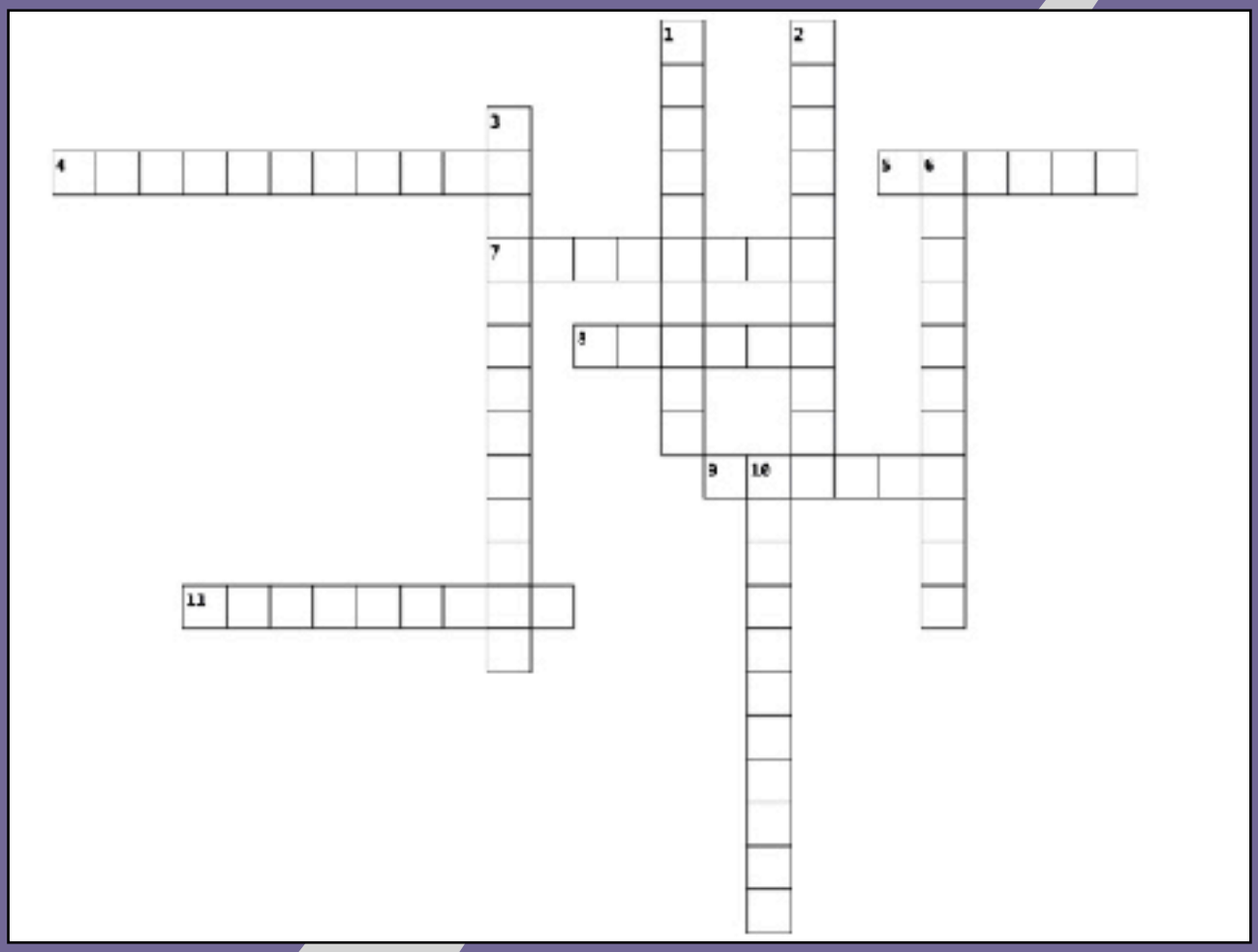
Armadillos
Armadillo mothers have an incredible ability to simply put their pregnancy on pause if the timing isn't right for them. This is known as 'embryonic diapause' and although it was first noticed in the 1850s, what causes it is still a mystery. It appears the hormones which cause embryonic diapause are different in all species which have the ability, and there isn't much correlation between the animals who can and those who can't: mice, deer, armadillos and kangaroos all can, whereas sheep, humans and most other animals cannot. A greater understanding of this phenomenon could lead to incredible strides in developing IVF treatment, as a more in depth look into the technicalities of early development would increase an awareness of which embryos are viable much earlier.

Kangaroos
Kangaroo fertilisation is not dissimilar to most mammals. However, the embryo does not for a placental connection, and therefore does not receive nutrients directly from the mother's body. Much like a bird egg, a kangaroo egg contains yolk, and once this is used up, the joey is born. At only 28 days old, the tiny kangaroo foetus must climb from the base of the mother's tail into her pouch, where it latches onto a nipple and remains for the rest of its development. At this point, it is possible for the kangaroo mother to become pregnant again, but much like armadillos, she can pause this pregnancy once the embryo reaches around 100 cells. This helps her replace her joey quickly if she happens to lose it, and will be able to quickly have another one once the current one has left the pouch for good.

Platypus
Unlike almost all other mammals, a platypus doesn't birth live young. Instead, she burrows into the riverbank and incubates her eggs for a week. Then, like all other mammals, she feeds her babies milk for 3-4 months before they are ready to go off into the world on their own.

Hammerhead sharks
In 2007, a female shark who had been kept captive and away from any males for 3 years, gave birth to a healthy baby. This phenomenon, known as parthenogenesis (Greek for 'virgin origin'), has been noted in several species, including other sharks and bees, but the mechanisms are not yet fully understood. It is thought that during egg development, one egg and three polar bodies produced and where, ordinarily, the polar bodies would simply be reabsorbed, if the number of chromosomes within a polar body matches the egg, fertilisation may occur. This is known as automatic parthenogenesis, and interestingly seems to only happen when the sharks are living with other females and not when they are alone.

Cross word



Across:
4. Impenetrable to fluids
5. Coil, helix, curl
7. e.g. Carbon 14
8. Best friend of Moderna
9. Sex cells
11. A doctor

Down:
1. Mathematically containing several terms
2. Red river
3. Causes meningitis
6. Female hyenas have...
10. Bacteria killers

Sudoku

7			3	2	6		8	9
							6	
9				7	8			2
	1	7	4	5			2	8
4	9	5				7	3	
6	2	8		3		9		5
8						2	9	
2			6					4
1			2		7		5	3

THANK YOU

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Thank you all so much for contributing to Issue 3 of Under the Microscope! And thank you to everyone who enjoyed reading this Issue. Join us next year for Issue 4...

Under the Microscope

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